DOCUMENT RESUME

ED 160 376 SE 024 887

AUTHOR	Wamsley, Mary Ann, Ed.; Verneire, Donna M., Ed.
TITLE	Aquatic Pest Control. Sale Publication 4071.
INSTITUTION	California State Polytechnic Univ., Pomona.; California Univ., Berkeley. Extension Div.
SPONS AGENCY	Environmental Protection Agency, Washington, D.C. Office of Pesticide Programs.
PUB DATE	Jan 77
CONTRACT	EPA-68-01-2918
NOTE	11p.; For related documents, see SE 024 886-891
EDRS PRICE	MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS	*Agricultural Chemical Occupations; Agricultural Education; Environment; *Herbicides; Manuals; *Pesticides; Science Education; *Water Resources; *Weeds

ABSTRACT

The information in this manual applies to control of aquatic pests in recreational waters, agricultural reservoirs, ornamental ponds, coastal bays, estuaries and channels, and drinking water reservoirs. Mechanical, cultural, biological, and chemical control methods are discussed. The majority of the material is devoted to weed control in static water, large impoundments, flowing water, and limited-flow waterways. Control of vertebrates is mentioned briefly. Environmental considerations and units and conversion equivalents are also covered. (BB)

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ED160376

AQUATIC PEST CONTROL

Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

SALE PUBLICATION
4071

PRINTED JANUARY 1977

SE 024887

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Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the United States Department of Agriculture. James B. Kendrick, Jr., Director, Cooperative Extension, University of California.

10m–1/77–VL/ME

ACKNOWLEDGMENTS

This guide has been developed by California State Polytechnic University, Kellogg West Center, under U.S. Environmental Protection Agency (EPA) contract number 68–01–2918. This contract was issued by the Training Branch, Operations Division, Office of Pesticide Programs, EPA. The leader of this group effort was Eugene D. Young, California State Polytechnic University, Kellogg West Center. Editors were Mary Ann Wamsley, EPA, and Donna M. Vermeire, North Carolina State University.

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PREFACE

Federal regulations establish general and specific standards that you must meet before you can use certain pesticides. University of California Cooperative Extension offices can provide material which you may study to help you meet the *general* standards. This guide contains basic information to help you meet the *specific* standards for applicators who are engaged in aquatic pest control.

This guide will give you information about:

- recognition and control of aquatic pests, and
- environmental concerns in aquatic pest control.

This publication provides essential information needed to meet the Environmental Protection Agency standards on Aquatic Pest Control, and to help prepare you to take the written examination for certification. It is not intended that this guide will provide you with all the knowledge you need for effective aquatic pest control. Additional information can be obtained from Cooperative Extension, University of California, and from your county agricultural commissioner.

INTRODUCTION

The demand for water resources for recreational, agricultural, industrial, and other purposes is increasing. Many kinds of plant and animal aquatic pests can interfere with these and other water uses. Control of aquatic pests is of national importance as a means of protecting these uses for the public.

The information in this manual applies to control of aquatic pests in:

- recreational waters used for fishing, boating, and aquatic sports,
- agricultural reservoirs and water distribution channels used for stock-watering, irrigation, and drainage,
- ornamental ponds,
- coastal bays, estuaries, and channels, and
- drinking water reservoirs.

Effective management of aquatic pests requires the combination of all appropriate control methods, including:

- mechanical,
- cultural,
- biological, and
- chemical.

AQUATIC WEEDS

The first step towards prevention or control of aquatic weeds is to identify them correctly. Most control methods are aimed at specific weeds or at groups of weeds with similar growth habits. Aquatic weeds can be grouped as follows:

- **Emersed aquatic weeds**—weeds that grow standing out of the water, or in water-saturated soils. Examples are cattails, bulrushes, and arrowheads.
- **Submersed aquatic weeds**—weeds that grow under the water surface. Examples are pondweeds, naiads, coontails, and watermilfoils.
- **Floating aquatic weeds**—weeds that float on the water surface. Examples are duckweeds, waterhyacinth, waterlettuce, waterferns, and waterlilies.
- **Algae**—weeds without true stems, leaves, or vascular systems. Examples are waternet, pithophora, and chara.

Many of these plants may be pests in some situations and desirable plants in others, depending on:

- their abundance and
- the use of the water they inhabit.

WEED CONTROL

CONTROL WITHOUT PESTICIDES

Pond and Ditch Design

Proper design and construction of ponds is an important factor in preventive control of weeds. Shallow water at the margins of ponds provides an ideal habitat for emersed weeds, such as cattail. Submersed weeds can easily become established there and then spread into deeper water. Banks should be sloped steeply so that there is very little water less than 2 or 3 feet deep.

Proper design and construction of ditches and channels makes weed control easier in the future. If the banks are leveled and smoothed, hard-to-reach places will be eliminated. Lining canals will help in alleviating water weed problems.

Mechanical Control

It may be necessary to use mechanical methods to control submersed weeds. Sources of water for drinking, for livestock, and for fish ponds often cannot be treated with chemicals.

- Chaining may be practical in some instances, particularly in canals.
- Drag lines are useful for cleaning canals and margins of lakes and ponds.
- Weed mowers are used in both canals and lakes for cutting weeds.

Some mowers simply cut the weeds loose beneath the water surface. Others (aquatic weed harvesters) collect the weeds for removal from the water. Disposal of harvested weeds is often a problem. Most methods of mechanical control fragment the weeds. This may actually aid in the spread of most species of weeds, since they may reproduce from the pieces. Mechanical control is usually slower and more costly than control of the same weeds with chemicals.

Draining and Drying

Some ponds, lakes, canals, and ditches may be drained so aquatic weeds will dry. The water levels in some large lakes and reservoirs may be lowered enough to expose weeds in shallow areas. Drying periods of several months may be needed to control weeds in some ponds and lakes. In canals, it may not be practical to interrupt water flow for longer than 3 or 4 days. The season of year and species of plant present may determine whether this method will be useful in a particular situation.

Be sure to consider the resident fish species and their normal spawning times.

Fertilization

Fertilization with inorganic nutrients may be a convenient and inexpensive method for control of weeds in ponds and small lakes. Fertilization stimulates a dense bloom of microscopic algae. The algae shade the pond bottom and prevent or reduce the growth of submersed weeds. Unless the fertilization is done correctly, however, the weed problem may become even more severe.

The fertilizer may be applied broadcast, applied from a boat, or dissolved in the water in other ways. Existing weeds either are not affected or their growth may be stimulated. You may need to remove them before fertilizing. Ponds that have a monthly water exchange greater than the capacity of the pond do not respond well to fertilization. Fertilizers ar more effective in deep water than in shallow water.

BIOLOGICAL CONTROL

Biological control is not often used. It has been successful in several situations. Biological control agents include:

- Tilapia—This plant-eating fish has only limited value. It will eat aquatic plants and reproduce rapidly, but it survives winter temperatures in only a very few areas of this country.
- White amur—The white amur is a large fish that eats large amounts of aquatic plants. It survives well in many areas of the United States. Because its environmental hazards are not fully known only a few States permit its use.
- Insects—Several insects have been brought into this country to control aquatic weeds. The most successful are a beetle and a moth that are parasitic on alligatorweed. They have provided good control of this weed in large areas of the South. Other insects are under study for control of other species of weeds.

CONTROL WITH PESTICIDES

Chemicals used in aquatic weed control are classified as herbicides. Herbicides used pr narily for control of algae are called algicides, even though they may also kill other aquatic plants. Aquatic herbicides are available in several formulations:

SPRAYABLE FORMULATIONS—Most herbicides are formulated to be mixed with a water carrier and sprayed. Some perform best as aquatic herbicides when applied into static or flowing water so that they disperse evenly and contact underwater surfaces of weeds. Kinds available are:

- water-soluble powders or crystals that form true solutions in water,
- wettable powders that can be suspended in water and applied,
- water-soluble liquid concentrates that form true solutions in water,
- emulsifiable liquid concentrates that form ordinary "oil-in-water" emulsions in water, and
- special liquid concentrates that form "water-in oil" emulsions (called invert emulsions) when mixed with water and oil in the spray tank or when applied through special mixing nozzles.

GRANULAR FORMATIONS—Many aquatic herbicides are used as dry granules of various sizes. Kinds available are:

- granulated pure chemical, such as crystalline copper sulfate,
- granules or larger-size pellets of clay and other materials impregnated with active ingredient, and
- slow-release granules or pellets designed to release the active ingredient in small amounts over an extended period of time in the water.

Application Techniques

Four zones of a body of water may be treated:

- the water surface,
- the total water volume,
- the bottom 1-to 3-foot layer of water, or
- the bottom soil surface.

SURFACE TREATMENT—Generally only ¼ to ⅓ of the surface area of the water should be treated at a time. This helps protect fish from a possible shortage of oxygen. Surface acreage of a rectangular body of water equals length in feet times width in feet divided by 43,560.

TOTAL WATER VOLUME TREATMENT—The whole body of water (from the surface to the bottom) is treated. Or you can treat ¼ to ⅓ of the total water volume (based on surface area) at a time. Calculate the volume of the body of water and add chemical to obtain the required dilution in the water.

The concentration of chemical needed to kill aquatic plants is often very small and is stated in parts per million (ppm).

If the toxicity level of a certain chemical for a particular aquatic weed is 2 ppm of active ingredient, for example, the chemical should be applied at a ratio of 2 parts of active ingredient to 1 million parts of water in the area to be treated.

First, calculate the acre-feet of the body of water to be treated. Multiply surface acres by the average depth in feet. An acre-foot of water weighs 2.7 million pounds. If one dissolves 2.7 pounds of any material in 1 acre-foot of water, there will be a concentration of 1 ppm by weight (ppmw). Use the following formula to determine the material needed to obtain a desired ppm concentration:

2.7 × ppm wanted × acre-feet = lbs. required

Assume one wants to treat a pond containing 10 acre-feet. The concentration of active ingredient required is 0.5 ppm. Using the formula:

2.7 × 0.5 × 10 = 13.5 lbs. of active ingredient

BOTTOM LAYER TREATMENT—Treating the deepest 1 to 3 feet of water is especially useful in deep lakes where it is impractical to treat the entire volume of water. Such treatments are generally made by attaching several flexible hoses at 3- to 5-foot intervals on a rigid boom. Each hose is usually equipped with some type of nozzle at the end. They may be weighted to reach the depth desired. The length of hose and speed of the boat carrying the application equipment also affect the depth of application. Successful bottom treatments apply the herbicide as a "blanket" in the lower 1 to 3 feet of water.

BOTTOM SOIL TREATMENT—Herbicide applications may be made to the bottom soil of a drained pond, lake, or channel.

Weed Control in Static Water

Static water is water in ponds, lakes, or reservoirs that has little or no inflow and outflow. Even totally enclosed bodies of water often have appreciable water movement because of wind and other factors. Weeds commonly grow in static water up to 12 feet deep. In very clear water, however, weeds sometimes grow in water 20 feet or more in depth.

FLOATING AND EMERSED WEEDS

Sprayable formulations are almost always preferred for floating and emersed weeds. These weeds are killed by direct foliage applications of the spray mixture:

- by aircraft,
- with ground equipment, operated from the bank if the pond is small, or if weeds occur only around the margins, or
- from a boat, using various types of booms or spray guns.

SUBMERSED WEEDS AND ALGAE

Herbicide formulations for control of submersed weeds and algae in static water may be sprays or granules.

Sprayable Formulations—Herbicide sprays are most often applied as water-surface treatments, particularly in shallow water. The herbicide is dispersed throughout the water by diffusion, thermal currents, and wave action. Sprayable herbicides can be applied under the surface by:

- injection through a hose pulled along behind a boat, or
- injection into the water by booms.

In all instances, control of the weeds depends on good dispersion of the chemical in the water.

Sprayable herbicides sometimes are used for bottom soil treatments.

Some sprayable herbicides may be applied from aircraft at low volumes of 5 to 10 gallons per acre.

Both surface and injection treatments made by boat or ground equipment are more effective and are easier when larger volumes of liquid carrier are used. A handy sprayer for making applications by boat uses a special pumping system that draws water from the lake or pond as the boat moves along. Concentrated herbicide is metered into the pumped water to achieve the concentration required. This avoids both frequent interruptions to prepare spray solution and the need to carry water on board.

Granular Formulations—The main aquatic use of granular herbicides is for control of algae or submersed weeds, although some are effective on certain emersed weeds. Because granules sink to the soil surface, they perform about the same way as herbicides applied as bottom soil treatments. Application rates for granular herbicides may be based on:

- amount of herbicide per unit of surface area, or
- the concentration (ppm) that would be achieved if the same amount of herbicide were dissolved and totally dispersed in the water (total water volume treatment).

Granular herbicides perform best when distributed evenly over the water surface. They may be broadcast by hand or manual spreader over small areas. Special granule spreaders mounted on aircraft or boats are used for large scale applications.

Advantages of granular herbicides are:

- treatment is usually confined to the bottom where the submersed weeds are,
- they can be made to provide a long contact time with weeds (slow-release granules),
- the herbicide concentration can be held to a low level, and
- they make it possible to use chemicals that in other formulations would be toxic to fish.

Weed Control in Large Impoundments

Herbicide applications that are successful in smaller bodies of water often perform poorly in large impoundments. These impoundments often have much water movement caused by thermal currents or the wind.

Weed control may sometimes be improved in these sites by:

- using the maximum recommended application rates,
- treating relatively large water areas at one time,
- applying herbicides only during periods of minimum wind,
- using bottom treatments in deep water,
- using granular formulations when possible, and
- selecting herbicides that are absorbed quickly by the weeds.

Weed Control in Flowing Water

Aquatic weeds in flowing water are the most difficult to control. Because the water is moving from one location to another, the possible hazards of herbicide use are greater.

Herbicides are sometimes used to control weeds in natural streams. Control of aquatic weeds in man-made water distribution and drainage systems is more common. Most of these carry irrigation water. Do not irrigate crops with treated water unless permitted by the herbicide label. Some systems also carry domestic, industrial, and recreational water. As the number of water uses increases, more restrictions and precautions are required.

FLOATING AND EMERSED WEEDS

These weeds, when in flowing water, require the same herbicides and treatment techniques as they do in static water. Precautions and restrictions are the same as those for control of submersed weeds in flowing water.

SUBMERSED WEEDS AND ALGAE

Effective control of these weeds can be achieved in flowing water only by continuously applying enough herbicide at a given spot to maintain the needed concentration and contact time.

The greater the cross sectional area of the stream and the greater the speed of flow, the larger the volume of water that must be treated.

The large volume of water that must be treated makes the use of herbicides in flowing water costly, particularly when:

- the weed infestation covers only a small area, or
- the herbicides are effective for only a short distance downstream.

Few herbicides are available for control of submersed weeds in flowing water. The more common ones are:

- Copper sulfate, used to control algae. It is toxic to trout at recommended treatment rates, but only moderately toxic to most other fish species. The toxicity of copper to fish increases with decreased total alkalinity of the water.
- Grade B xylene and acrolein, which are highly toxic to fish and many other forms of aquatic life. They are used primarily in water delivery systems that contain no fish, or where the water delivery is far more important than the value of the few fish that might be present.

Be sure that the residues in the treated water and runoff water are at or below the levels permitted for all subsequent uses.

Weed Control in Limited-Flow Waterways

Flood drainage canals, sloughs, and drains are good examples of limited-flow waterways. Weed control methods in these systems of little water movement are very similar to those used in static water. Consider the possible contamination of water used for other purposes when you plan the use of herbicides in limited-flow water. In some areas, drainage water may flow directly on to cropland or be used for irrigation, or it may enter a fishery or drinking water supply.

VERTEBRATES

FISH

Some species of fish are considered pests in certain areas and situations. The major kinds of pest fish are:

- those that compete with more desirable fish for food, space, and other necessities of life,
- those that affect man's interest or livelihood, and
- those that prey or feed upon more desirable fish.

Control

The control of pest fish varies with each situation and species. Some problems are not serious enough to justify any action. In other situations, control is necessary and can be justified on sound biological grounds. Some pests may also be protected game fish, so control methods that do not harm the pest species may be the only legal solution.

NONCHEMICAL CONTROL includes temporary draining of small bodies of water or using physical methods such as traps, net or screen barriers, or barrier dams.

CHEMICAL CONTROL requires the use of piscicides. The use of fish control chemicals is a highly specialized area of pest control. Few chemicals are registered for this purpose. Use special care when applying them.

MAMMALS

Rodents are of the most concern. They include:

- beaver,
- nutria,
- muskrats, and
- rats.

Damage includes:

- burrowing, which structurally weakens earthen dikes, levees, and dams; causes water losses or flooding; and increases erosion of banks,
- increasing suspended sediment in water,
- clogging culverts or water pipe intakes with vegetation cut during feeding or nest-building activities, and
- blocking stream flow.

Control

Depending on the pest species and the situation, the following control methods may be used:

NONCHEMICAL CONTROL, including:

- modifying or controlling habitat, such as controlling weeds to reduce food supplies,
- installing dike protectors or barriers,
- trapping, or
- shooting.

CHEMICAL CONTROL, including the use of:

- repellents,
- fumigants, and
- baits.

Other Vertebrates

A few birds, reptiles, and amphibians may cause some problems in local areas. Chemicals are rarely used to control them.

ENVIROMENTAL CONSIDERATIONS AND RESTRICTIONS

Incorrect application of herbicides in water may involve serious hazards to man, wildlife, fish, and desirable plant life. Consequently, you must:

- select the correct herbicide for a specific aquatic site and particular weed infestation,
- apply it correctly at recommended rates,
- observe the restrictions on use of the treated water,
- be aware of the adverse effects of incorrect use, and
- obtain permission if necessary from appropriate State or Federal agencies.

The control of aquatic vegetation presents special problems, because:

- the water often has multiple uses and
- herbicides will not always remain where they are placed.

Consider all the uses of the water to be treated, including those far downstream. Read the label to determine that the herbicide you choose is compatible with these uses.

Types of water uses to consider before applying herbicides include:

- human use, such as drinking, cooking, and swimming. Few tolerances have been established for herbicide residues in such water. Copper sulfate has been used for control of algae in drinking water for many years and is permitted at the concentration of 1 ppm copper ion. Limited residues of several other herbicides are permitted in raw drinking water. However, you should avoid contaminating any drinking water with any level of herbicide.
- livestock and wild animal use,
- irrigation,
- industrial uses, and
- fish production—Most aquatic herbicides are not toxic to fish or other animal life at the concentrations recommended for weed control. Notable exceptions are Grade B xylene, acrolein, and some solvents and emulsifiers in certain formulations of normally nontoxic herbicides. These should not be used in fisheries, or where the water treated with these herbicides could enter fishery waters.

  It is possible to use these herbicides for treatment of small plots, or for treatment of weed-infested marginal areas, with little hazard to fish. If given an avenue of escape, fish will leave areas where the herbicide is used.

  Trout are especially susceptible to copper sulfate. Trout waters should not be treated with copper sulfate without consulting fish biologists.

Application Rates

Correct application of herbicides to aquatic situations involves equipment calibration and calculation of appropriate water volumes or areas. Environmental hazard can result from the incorrect application rate.

Excessive application can cause:

- damage to fish, either from direct toxicity, or from lack of oxygen caused by an excessively rapid kill of plants. Bacterial contamination resulting from decay of killed fish might further contaminate downstream water supplies.
- the need for exclusion of livestock from use of the water for a longer time than necessary, and
- water unfit for irrigation use.

State and Federal Regulations

Many States have regulations which govern the use of pesticides in water. Check with the appropriate agency when in doubt. There are also stringent Federal and some State regulations controlling the importation of exotic fish or plants.

For additional information on vertebrates see applicator training guide: "Vertebrate Pest Control".

UNITS AND CONVERSION EQUIVALENTS

1 acre = 43,560 sq ft
1 acre-foot (A-ft = 43,560 cu ft = 325,872 gal = 2,720,000 lb of water
1 cu ft per second (cfs) = 450 gallons per minute (gpm)
1 cu ft = 7.48 gal = 62.4 lb of water
1 gal = 128 fluid ounces = 8.33 lb of water
1 part per million by volume (ppmv) = 1gal per million gal of water
1 part per million by weight (ppmw) = 8.33 lb of chemical per million gal of water
1 ppmw = 2.72 lb of chemical per A-ft of water gal of liquid formulation required

$$= \frac{\text{lb ai required}}{\text{lb ai per gal of concentrate}}$$

$$\text{lb of dry formulation required} = \frac{\text{lb ai required} \times 100}{\%\text{ ai in formulation by weight}}$$

(ai = active ingredient)

FORMULAS FOR HERBICIDE APPLICATION TO CHANNELS

cfs = cross section area in sq ft × average velocity in ft per second (fps)
Cross section area of rectangular channel in sq ft = average width in feet times the average depth in ft

$$\text{ppmv} = \frac{\text{gal of chemical} \times 1{,}000{,}000}{\text{cfs} \times 450 \times \text{minutes applied}}$$

$$\text{gal of chemical per cfs} = \frac{\text{ppmv} \times 450 \times \text{minutes applied}}{1{,}000{,}000}$$

$$\text{Total gal of chemical required} = \frac{\text{ppmv} \times 450 \times \text{cfs} \times \text{minutes applied}}{1{,}000{,}000}$$

$$\text{ppmw} = \frac{\text{lb of chemical} \times 1{,}000{,}000}{\text{cfs} \times 3744 \times \text{minutes applied}}$$

$$\text{ppmw} = \frac{\text{gal of formulation} \times \text{lb ai per gal} \times 1{,}000{,}000}{\text{cfs} \times 3744 \times \text{minutes applied}}$$

$$\text{lb of chemical per cfs} = \frac{\text{ppmw} \times 3744 \times \text{minutes applied}}{1{,}000{,}000}$$

$$\text{gal of formulation per cfs} = \frac{\text{ppmw} \times 3744 \times \text{minutes applied}}{\text{lb ai per gal} \times 1{,}000{,}000}$$

FORMULAS FOR HERBICIDE APPLICATION TO PONDS OR LAKES

Volume of pond in cu ft = surface area in sq ft × average depth in feet
Volume of pond in A-ft = surface area in acres × average depth in feet

$$\text{Volume of pond in A-ft} = \frac{\text{volume of pond in cu ft}}{43{,}560}$$

$$\text{ppmv} = \frac{\text{gal of 100\% active ingredient}}{\text{volume in A-ft} \times 0.33}$$

$$\text{Total gal of chemical required} = \text{A-ft} \times \text{ppmv} \times 0.33$$

$$\text{ppmw} = \frac{\text{lb ai of chemical applied}}{\text{volume in A-ft} \times 2.72}$$

$$\text{Total lb ai required} = \text{A-ft} \times 2.72 \times \text{ppmw desired}$$

$$\text{Total gal of liquid formulation required} = \frac{\text{A-ft} \times 2.72 \times \text{ppmw desired}}{\text{lb ai per gal of concentrate}}$$